

[54] PRODUCTION OF  $^{123}\text{I}$ 

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[22] Filed: July 12, 1973

[21] Appl. No.: 380,046

## Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 247,434, April 25, 1972.

[52] U.S. Cl. .... 176/11; 176/16; 176/14; 250/400; 250/429; 250/492 R

[51] Int. Cl.<sup>2</sup> ..... G21G 1/10

[58] Field of Search ..... 176/11, 16, 14; 423/249; 250/429, 400, 492, 432

## [56] References Cited

## UNITED STATES PATENTS

2,795,482 6/1957 McNabney ..... 423/249

3,018,159 1/1962 Silverman ..... 423/249  
3,694,313 9/1972 Blue et al. .... 176/16

## OTHER PUBLICATIONS

Bulletin of the Chemical Society of Japan, Feb. 1970, vol. 43, No. 2, p. 576, Kato et al.

Isotopes and Radiation Technology, vol. 4, No. 3, 1967, pp. 275-280.

Uses of Cyclotrons in Chemistry, Metallurgy and Biology, Proc. Conf., Sept. 1969, pp. 138-148, Blue et al.

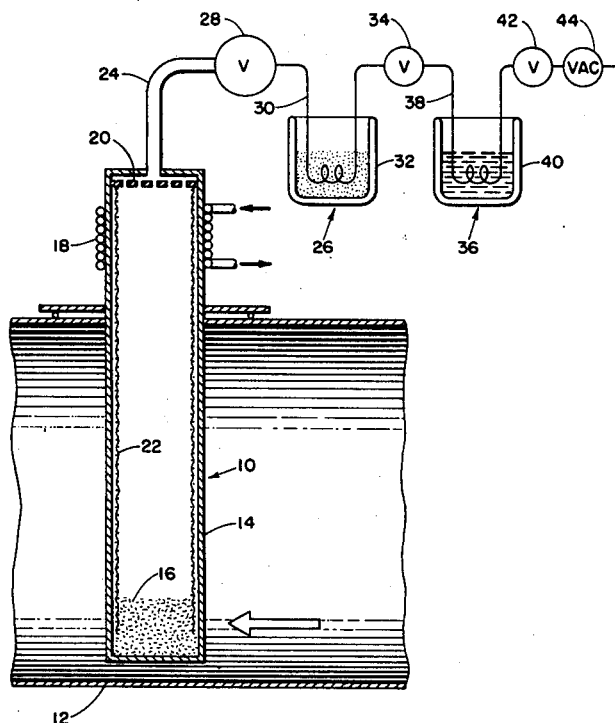
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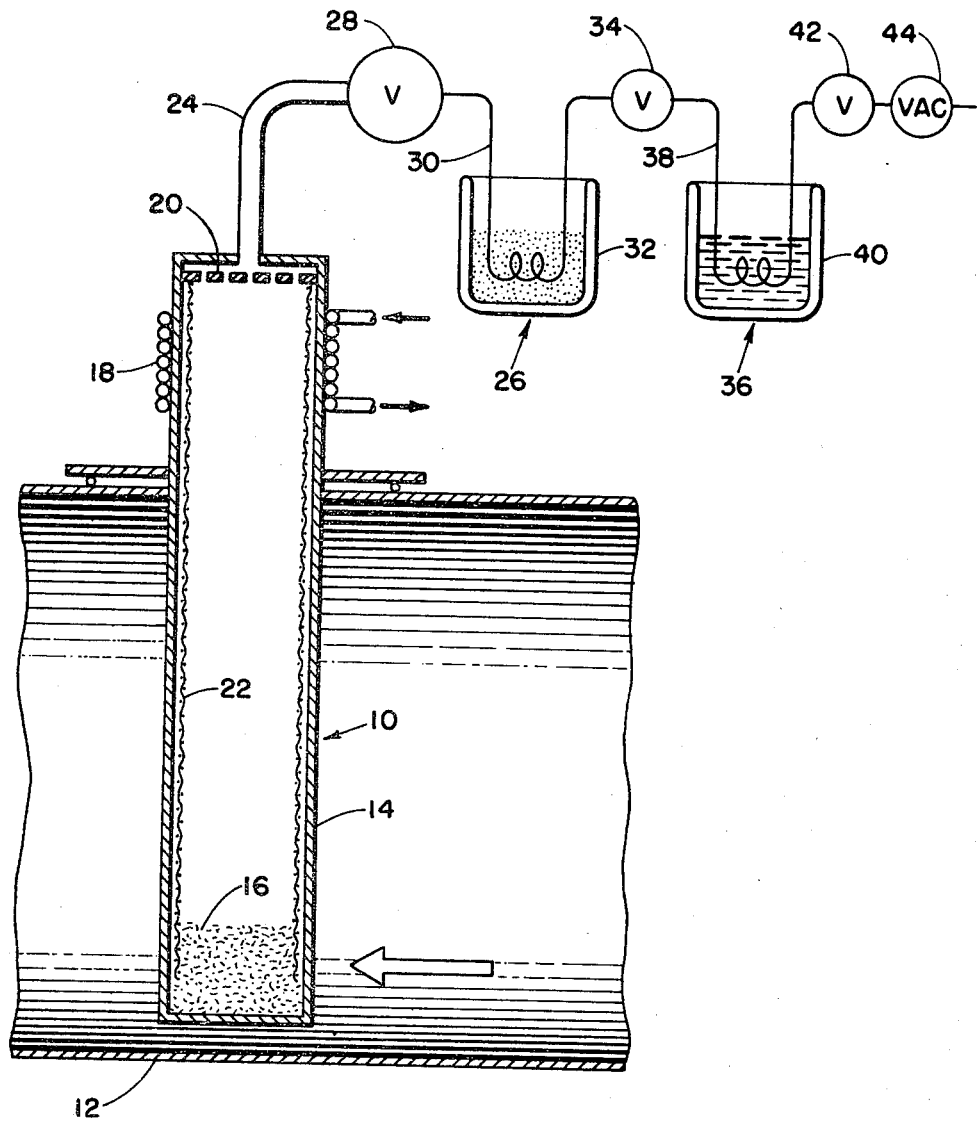
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## [57] ABSTRACT

Bombarding a cesium heat pipe with high energy particles causes a spallation reaction which produces vapors of  $^{123}\text{Xe}$  and contaminants. The contaminants are removed in a dry ice cold trap while the  $^{123}\text{Xe}$  condenses in a liquid nitrogen trap where it decays to  $^{123}\text{I}$ .

6 Claims, 1 Drawing Figure





## PRODUCTION OF $^{123}\text{I}$

### ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

### STATEMENT OF COPENDENCY

This application is a continuation-in-part of application serial No. 247,434 which was filed Apr. 25, 1972.

### BACKGROUND OF THE INVENTION

This invention is concerned with the production of high purity radioiodine for thyroid measurements and as a general radionuclide. The invention is particularly directed to the utilization of a heat pipe in the production of radioisotopes using very intense particle accelerators.

Radioactive iodine is used for medical diagnostic studies. The isotope  $^{131}\text{I}$  has been used for this purpose because of its availability. The radioisotope  $^{123}\text{I}$  is considered much superior to the  $^{131}\text{I}$  in studies where the amount of radiation exposure to a patient is of prime concern. Because of the shorter half-life and the decay by electron capture, the radiation exposure received by the patient from  $^{123}\text{I}$  is about one-fortieth that of an equal amount of  $^{131}\text{I}$ .

$^{123}\text{I}$  is also superior to  $^{131}\text{I}$  because the gamma ray energy of  $^{123}\text{I}$  is 159 KEV compared to 364 KEV of  $^{131}\text{I}$ . Collimators operate more effectively with this lower energy. Also the collimators used with  $^{123}\text{I}$  are less bulky.

A method of  $^{123}\text{I}$  production is disclosed in U.S. Pat. No. 3,694,313. The method disclosed in this patent has been quite successful in terms of freedom from radioactive impurities. However, the method is not capable of handling the power densities involved in using high energy, high current machines.

### SUMMARY OF THE INVENTION

According to the present invention cesium is used both as the working fluid of a heat pipe and as the target material for high energy protons. A spallation reaction produces  $^{123}\text{Xe}$  and many radioactive contaminants which pass from the heat pipe to low temperature traps where the undesirable contaminants are removed. The xenon is held for a period of time sufficient for it to decay to  $^{123}\text{I}$ .

### OBJECTS OF THE INVENTION

It is, therefore, an object of the invention to produce the radioisotope  $^{123}\text{I}$  with high energy particles from very intense particle accelerators.

Another object of the invention is to produce  $^{123}\text{I}$  using a heat pipe that is bombarded with high energy particles.

These and other objects of the invention will be apparent from the specification which follows and from the drawing wherein like numerals are used throughout to identify like parts.

### DESCRIPTION OF THE DRAWINGS

The drawing is a schematic view of an apparatus for producing radioactive iodine in accordance with the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing there is shown a target assembly which extends into a beam duct 12 of a high energy accelerator. It is contemplated the target assembly 10 may be used with the LOS ALAMOS MESON FACILITY, known as LAMF. Another high energy accelerator located in Canada, called TRIUMF, would be a suitable source of high energy particles. The beam in the duct 12 from such accelerators is characterized by high energy between 200 MeV and 2000 MeV and high current.

The target assembly 10 is in the form of a heat pipe which comprises a tubular container 14 having a supply 16 of cesium-133 in the end which extends into the beam duct 12. The opposite end of the tube 14 which protrudes from the duct 12 is surrounded by cooling coils 18. A suitable cooling fluid, such as water, is circulated through the coils 18.

A porous metal plug 20 is mounted in the container 14 adjacent to the cooling coils 18. A wick 22 extends along the inner wall of the tube 14 between the plug 20 and the cesium 16.

A tube 24 connects the inside of the container 14 to a cold trap 26 through a valve 28. Tygon tubing has been satisfactory for the tubular conduit 24. The cold trap 26 comprises a U-tube 30 immersed in a coolant in an insulated container 32. A one-fourth inch copper U-tube surrounded by solid  $\text{CO}_2$  in a Dewar has been satisfactory. The dry ice maintains a trap 26 at a temperature of  $-79^\circ\text{C}$ .

A valve 34 connects the dry ice trap 26 to a second cold trap 36. A one-fourth inch copper U-tube 38 immersed in liquid nitrogen in a Dewar 40 has been satisfactory for the cold trap 36. The liquid nitrogen maintains the trap 36 at a temperature of  $-196^\circ\text{C}$ . A valve 42 is used to isolate the trap 36 or connect it to a vacuum pump 44.

In operation, a beam of high energy protons identified by the arrow in the duct 12 penetrates the tubular container 14 and strikes the cesium-133 in the target assembly 10. The beam penetrating the cesium causes what is known in nuclear physics as a spallation reaction which produces  $^{123}\text{Xe}$  according to the reaction  $^{133}\text{Cs}(\text{p,p } 10\text{n})^{123}\text{Xe}$ .

This is only one of a number of reactions that lead to significant impurities. Some of these reactions are  $^{133}\text{Cs}(\text{p, } 2\text{p } 8\text{n})^{124}\text{I}$ ,  $^{133}\text{Cs}(\text{p, } 2\text{p } 7\text{n})^{125}\text{I}$ ,  $^{133}\text{Cs}(\text{p, } 2\text{p } 6\text{n})^{126}\text{I}$ ,  $^{133}\text{Cs}(\text{p, } 3\text{p } 8\text{n})^{123}\text{Te}$ ,  $^{133}\text{Cs}(\text{p, } 4\text{p } 6\text{n})^{124}\text{Sb}$ .

To produce these spallation reactions the incident proton must have an energy greater than 200 MeV. The first three reactions produce the radioactive iodines  $^{124}\text{I}$ ,  $^{125}\text{I}$  and  $^{126}\text{I}$ . These radioactive iodines would seriously contaminate the desired  $^{123}\text{I}$  because they cannot be chemically separated. The other impurities formed by the above listed reactions could be separated chemically because they are different elements. However, this is not necessary in the heat pipe device because all of the impurities have a lower vapor pressure than the desired  $^{123}\text{Xe}$  and can be collected on cool surfaces at the heat rejection end of the heat pipe. Radioactive isotopes of iodine, tellurium, antimony, tin, indium, and cesium are all contaminants.

All of the isotopes of hydrogen and helium could be accelerated to hundreds of MeV and produce the desired spallation reaction. An example would be  $^{133}\text{Cs}(\alpha$ ,

3p 11n)<sup>123</sup>Xe. The same contaminants as produced by proton bombardment would also be produced.

The beam penetrating the cesium-133 deposits energy in the cesium that heats this target to the point where it vaporizes. All charged particle beams lose energy by ionizing and exciting electrons on the atoms of the stopping material, such as cesium. The individual particles that make up the beam actually lose velocity in a continuous manner. This energy lost by the beam appears as heat, and if the beam current is large enough this heat will melt metallic cesium and vaporize it. The vapor is transported to the end of the tubular chamber 14 where it is cooled by the cooling coils 18. The temperature at the hot end of the heat pipe is 670°C which is the boiling point of cesium. The temperature at the cold end is above the melting point and below the boiling point of cesium. This temperature must be above the melting point for the apparatus to be suitable for its intended use because the cesium must condense as a liquid thus giving up the heat of vaporization. Then as a liquid the cesium flows back to the hot end of the heat pipe. It is not difficult to achieve this condition in practice because the cesium vapor column and the cesium condensed on the wall of the heat pipe make the column nearly isothermal.

In one embodiment it is possible to have a sharp temperature drop when the column is run as a two component heat pipe where one phase is a non-condensable gas. Even in this embodiment it is not difficult to achieve heat pipe operation although there may be some solid cesium on the walls.

The cesium condenses at this cool end of the tube. The beam power that was deposited in the cesium is rejected to the coolant that flows in the coils 18.

Some small amount of cesium vapor may be transported through the plug. However, most of the cesium vapor will be collected on the cool walls because the vapor has a greater opportunity to contact the cool walls than the plug. The <sup>123</sup>Xe, <sup>125</sup>Xe, <sup>123</sup>I, <sup>124</sup>I, <sup>125</sup>I, <sup>126</sup>I, and <sup>129</sup>I will pass through the plug plus smaller amounts of other contaminants. All these elements passing the plug will be subsequently stopped by cooler surfaces except for xenon. Xenon will not be collected until it is pure and free of contaminants.

The <sup>123</sup>Xe and other volatile contaminants also travel to the cool end of the tube 14 where they pass through the tube 24 and valve 28 to the cold trap 26. The porous metal plug 20 prevents accidental transport of liquid cesium into the trap 26 which might take place where boiling occurs. The vapors of radioactive contaminants condense in the trap 26.

The <sup>123</sup>Xe is still a vapor and passes to the trap 36 at liquid nitrogen temperature. The <sup>123</sup>Xe condenses in the trap 26. The removal of the xenon from the vapor phase produces a pumping action that causes almost all the xenon that is produced to be transported to the trap 36.

The cesium vapors that condense in the heat pipe at the coils 18 are transported back to the target area by capillary action of the wick 22. It is also contemplated that grooves in or on the inner wall of the tubular container 14 may be used to transport the condensed cesium vapors back to the target area.

It is apparent the target assembly 10 uses cesium as both a heat pipe working material and as a target material for the production of radioisotopes by high energy charged particles. Cesium -133 is the preferred working material because of the uniqueness of its heat-trans-

fer properties, such as enthalpy, melting point, boiling point and vapor pressure-temperature curve. No other element has these properties together with the nuclear requirements as required by the target material.

Although the preferred embodiment has been shown and described it is contemplated that various structural modifications may be made to the disclosed apparatus without departing from the spirit of the invention or the scope of the subjoined claims. By way of example, it is contemplated that different trap configurations could be utilized. The trap 26 could be a chemical trap, such as hot silver, to remove radioiodine impurities. The <sup>123</sup>Xe trap 36 could work on the absorption principle.

The trap 34 could also contain a pharmaceutical compound that would become tagged or labeled when the xenon decays to iodine. It is generally desirable to select a pharmaceutical that goes to a specific organ where it is involved in some metabolic process. Hippuran goes to the kidney and has been tagged with <sup>123</sup>I by placing it on the walls of a container and condensing <sup>123</sup>Xe on these same walls. Other pharmaceuticals that could be labeled are human serum albumin, cholesterol, dopamine and fibrinogen.

What is claimed is:

1. In combination with a high energy accelerator having a duct containing a beam of particles having high energy between 200 MeV and 2000 MeV and current sufficiently high that the total beam power is greater than two kilowatts, apparatus for producing <sup>123</sup>I comprising

a heat pipe comprising a tubular container extending into said duct, a portion of said tubular container being in the path of said high energy beam,

a supply of cesium 133 in said portion of said tubular container in said beam, said cesium 133 being bombarded by said beam thereby vaporizing the same and producing radioactive isotopes of xenon including <sup>123</sup>Xe and contaminants selected from the group consisting of iodine, tellurium, antimony, tin, indium and cesium by spallation,

cooling means around a portion of said tubular container remote from said portion of said beam for condensing said vaporized cesium,

a first trap connected to said heat pipe for receiving said radioactive isotopes of xenon and the contaminants after the same have vaporized and removing said radioactive isotopes of said contaminants, and a second trap connected to said first trap for receiving said radioactive isotopes of xenon therefrom and removing the same, said second trap forming a container for holding said radioactive isotopes of xenon for a period of time sufficient for the <sup>123</sup>Xe to decay to <sup>123</sup>I.

2. Apparatus as claimed in claim 1 wherein the first trap contains solid carbon dioxide.

3. Apparatus as claimed in claim 1 wherein the cooled portion of the heat pipe extends outside the duct.

4. Apparatus as claimed in claim 1 including a porous metal plug in said heat pipe adjacent to said cooling means for preventing cesium from being transported to said first trap.

5. Apparatus as claimed in claim 1 wherein the second trap contains a pharmaceutical compound whereby said pharmaceutical compound is tagged when the <sup>123</sup>Xe decays to <sup>123</sup>I.

6. In apparatus for producing <sup>123</sup>I wherein radioactive isotopes of xenon including <sup>123</sup>Xe and contaminants

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selected from the group consisting of iodine, tellurium, antimony, tin, indium and cesium are passed through cold traps to sequentially remove the radioactive isotopes of contaminants and xenon, the improvement comprising

a beam of protons having an energy greater than 200 MeV,

a heat pipe having one end extending into said beam

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and the other end in communication with said cold traps, and  
a supply of cesium 133 target material in said one end of said heat pipe whereby said cesium 133 is bombarded by said beam thereby vaporizing the same and producing the radioactive isotopes of xenon and contaminants by spallation.

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